MFA 200

Resonance Analyzer

Universal Evaluation Platform
for Resonant Systems

Features

- Measures resonance frequency, quality factor resonance amplitude and phase angle
- Can be used with virtually any type of resonator
- Real–time resonance parameter extraction
- Up to 4 measurements per second
- Resonator frequency range: 100 Hz – 60 kHz
- Precise resonance fit even for very low quality factors ($Q \approx 10$)
- Fast tracking of dynamic processes
- USB–connection to PC or control computer
- Operation via software GUI
- Real–time data export

Applications

- Analysis of resonant structures
- Evaluation of resonant sensors
- Viscosity and density sensors
- Fluid level measurement
- Condition monitoring
- Conductivity and permittivity measurement

The MFA 200 is a universal, high precision evaluation platform for resonant sensors. It provides an excitation signal generator, a response signal analyzer and a digital signal processing stage extracting the parameters of the resonator from excitation and response signals. The resonator parameters are reported to a PC, where it can be visualized in a graphical user interface and exported to other applications.

The MFA 200 utilizes a special resonator tracking mode developed to minimize the impact of disturbances and parasitic influences on the obtained measurement results (patent pending). Furthermore this method suppresses sweeping artifacts as they occur with impedance or network analyzer instruments. With this technology, the resonator behavior is tracked continuously yielding a high measurement repetition rate with minimal noise on the obtained measurement results.

The measurement unit can be used with virtually any type of resonator, independent of its physical implementation. This comprises quartz crystal resonators, mechanical resonators with piezoelectric couplers, electromagnetic resonators, as well as resonators where excitation and readout mechanisms are not the same (e.g. electromagnetically actuated cantilever with optical readout).

1 Technical Data

Description	Minimum	Typical	Maximum	Unit
GENERAL				
Ambient Temperature	10		50	°C
Frequency Range	100		60000	Hz
Measurement Repetition Rate[1]			4	s^{-1}
Ref. Clk Stability (over Temp.)			±2.5	ppm
Ref. Clk Drift			±1	ppm/year
Data Converter Sampling Rate[2]		200		kSPS
ANALOG IO				
Full Scale Output Voltage (Single Ended)			7	Vpp
Full Scale Input Voltage (Single Ended)	6.19	6.66	7.13	Vpp
Input Common Mode Level	−0.5		2	V
Output Common Mode Level		±100		mV
Single–Ended Output Impedance		1.5		kΩ
Single–Ended Input Impedance		34		kΩ
Noise Floor			−120	dB_{FS}
Harmonic Distortion (HD2 & HD3)		−89		dB_C
POWER SUPPLY				
Supply Voltage	9		12	V
Supply Current (@9V)		420	1000	mA
± 5V External Supply Current			200	mA

[1] This value is equivalent to the sweeping duration of impedance/network analyzers.
[2] To achieve optimal system performance, the sampling rate of the converters are tuned upon mode of operation.

2 Connections

2.1 Sensor Port

Sensors are connected to the MFA 200 via the sensor port. The Connector is a common RJ45 type providing the analog signals for resonator excitation and detection on 2 separate subchannels respectively. Pin numbering scheme and pinout are shown in Fig. 1 and Tab. 1.
Excitation as well as detection signals are provided as (symmetric) differential pairs.
Standard network cabling can be used to connect sensors or sensor interfaces to the sensor port.
Note: Do not connect this port to local area network devices.

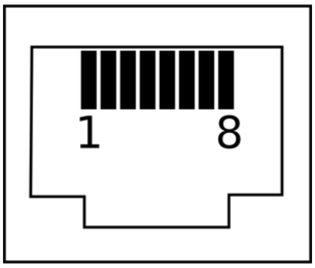

Figure 1: Sensor Port Pin Numbering (Receptacle, Front View)

Pin	Description
1	excitation 2 –
2	excitation 2 +
3	detection 1 –
4	excitation 1 +
5	excitation 1 –
6	detection 1 +
7	detection 2 –
8	detection 2 +
screen	Ground

Table 1: Sensor Port Pinout

2.2 Extension Connector

The extension connector is a 10 pin IDC connector that can be used to provide power to external circuits like sensor interface circuits. Please consider the supply current limitation. Pin numbering scheme and pinout are shown in Fig. 2 and Tab. 2. It is recommended to use ferrite beads at the power inputs of external circuits.
Note: consider the ground connection at the sensor port to avoid ground loops.

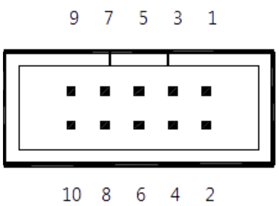

Figure 2: Extension Connector Pin Numbering (Receptacle, Front View)

Pin	Description
1 – 4	reserved, do not connect
5, 6	ground
7, 8	–5V supply
9, 10	+5V supply

Table 2: Extension Connector Pinout

2.3 USB

The MFA 200 is connected to a PC via an USB 2.0 Type B connector. A virtual com port (FTDI driver) is used for communications with the MFA 200.

2.4 LAN

Not available in this version.

3 Detailed Description

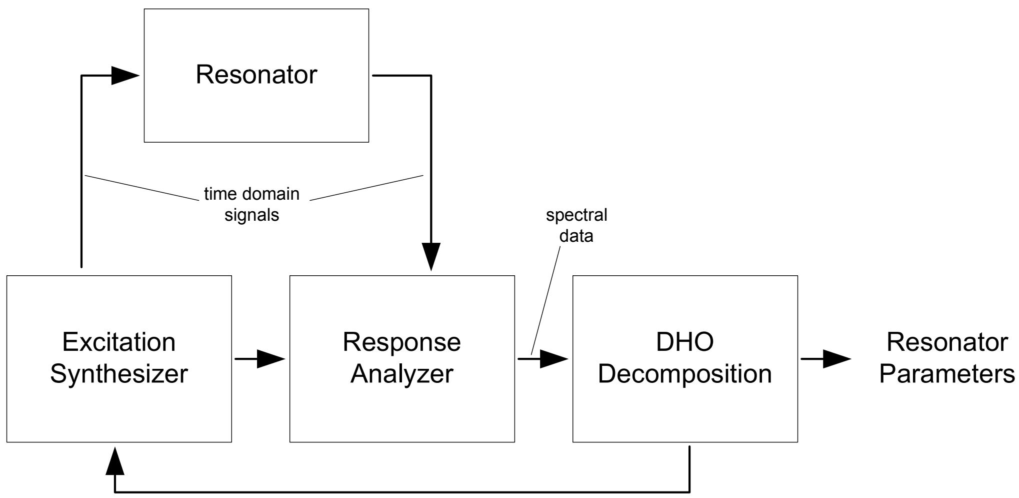

Figure 3: System Overview.

3.1 Excitation and Detection

The MFA 200 is an universal evaluation platform for resonant sensors covering the complete evaluation process from sensor excitation to extraction of resonator parameters from the response signals. The most simple oscillator is called *simple harmonic oscillator*, a system with two independent lossless energy storages where energy is moved in between. If the system is lossy, it is called *damped harmonic oscillator* (DHO). The most common mechanical representation of such a system is the damped spring pendulum, in the electrical domain it is the RLC resonant circuit.

Only very few physical resonators can be modeled with a DHO only, in most cases the resonator models have to be extended with additional elements in order to describe parasitic effects. These effects comprise finite resistance of conductive paths, capacitive or inductive coupling as well as phase shifts or propagation delays. The signal components introduced by these elements are called *spurious* or *parasitic*.
In the MFA 200 a dedicated signal processing unit separates the behavior of the DHO from parasitic signal components before the parameters of the resonance are calculated. With this technology the measurement results are robust against changes of parasitic influences.

Measurements are performed in several steps which are continuously running in parallel:

- excitation of the resonator
- analyzing the response signal
- calculating the resonator behavior
- separating the DHO behavior from parasitic signal components
- calculating DHO parameters
- tuning the excitation signal upon DHO parameters

The MFA 200 utilizes a special resonator tracking mode developed to minimize the impact of disturbances and parasitic influences on the obtained measurement results. Furthermore this method suppresses sweeping artifacts as they occur with impedance/network analyzer instruments. With this technology, the resonator behavior is tracked continuously yielding a high measurement repetition rate with minimal noise on the obtained measurement results.

3.2 Sensor Connection

The MFA 200 can be used with virtually any type of resonator, independent of its physical implementation. This comprises quartz crystal resonators, mechanical resonators with piezoelectric couplers, electromagnetic resonators, as well as resonators where excitation and readout mechanisms are not the same (e.g. electromagnetically actuated cantilever with optical readout).

In order to match the properties of the resonator to the sensor port of the MFA 200 a sensor frontend electronics can be used. This sensor frontend, which can be located close to the resonator, can be powered using the ±5 V power from the extension connector on the front panel of the MFA 200. The analog interface of the MFA 200 is based on differential signals (Fig. 4), which enables long distances between sensor frontend and MFA 200. As the ports are equipped with standard RJ45 connectors, common network cables can be used for this connection.

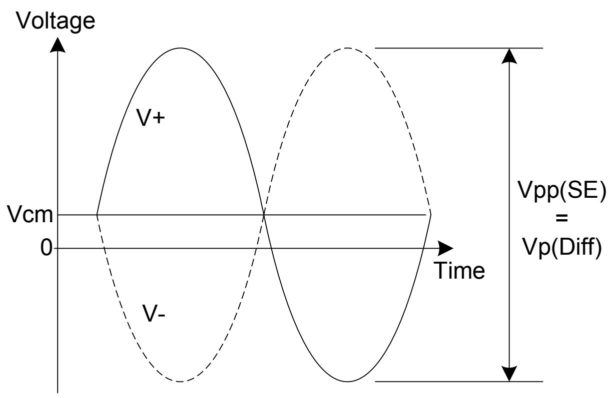

Figure 4: Differential signal levels.

Twoport (four terminal) resonator devices can be connected directly (considering signal levels), if oneport (two terminal) resonators are used, a sensor frontend circuit is required in almost any case. A simplified example for an interfaces circuit for a quartz crystal tuning fork is shown in Fig. 5.

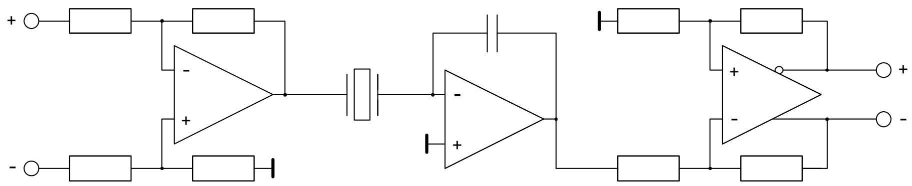

Figure 5: Sensor frontend for a quartz tuning fork resonator (simplified).

The sensor port provides 2 individual subchannels for both excitation and detection, which allows the connection of 2 sensors at the same time. The desired subchannel used for measurement can then be selected in Resonance–Analyzer.

3.2.1 Calibration

The MFA 200 evaluates the behavior of the attached device from its inputs to its outputs. When a sensor frontend is used, the effect of this circuit has to be considered in order to derive the parameters of the resonator only. Therefor it is required to run a setup calibration procedure before starting the measurements. To cover the variety of possible sensor frontend circuits the MFA 200 offers several calibration models to choose from. For more information please refer to the user manual of Resonance–Analyzer.

3.3 Dynamic Sensor Behavior

Damped harmonic oscillators have a time constant

$$\tau = \frac{1}{\pi b}$$

that is inversely proportional to the bandwidth of the resonator. Due to this time constant the maximum measurement rate that can be achieved with resonant sensors is limited, depending on the operation condition. For reliable use it is recommended to use measurement rates slower than $1/(10\ \tau)$ (see Fig. 6).

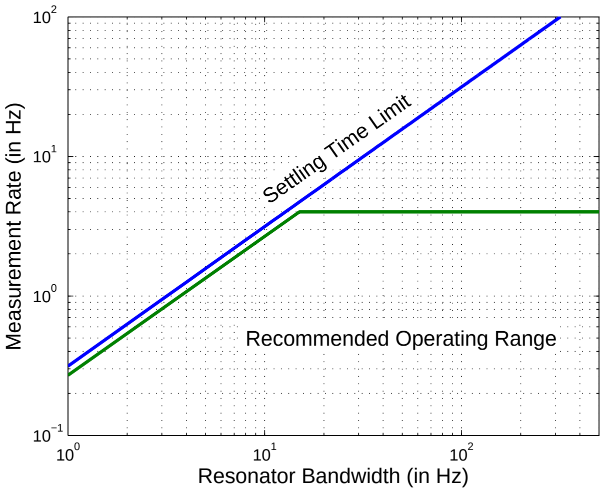

Figure 6: Measurement rate vs. resonator bandwidth.

4 Statistical Behavior

For many types of resonators and resonator interface circuits, the resonant behavior is afflicted with parasitic signal components causing a significant amount of the signal amplitude (Fig. 7). For the performance of the measurement system not the overall signal amplitude but the amplitude of the resonance A_{R} is of interest. Consequently, when estimating noise on the obtained resonance parameters from a known signal to noise ratio (SNR) of the overall analog signals, the signal to noise ratio relevant for the measurement system has to be reduced by the fraction of useful to maximum signal amplitude

$$\mathrm{SNR_R} = \frac{A_{\mathrm{R}}}{A_{\mathrm{max}}} \cdot \mathrm{SNR}.$$

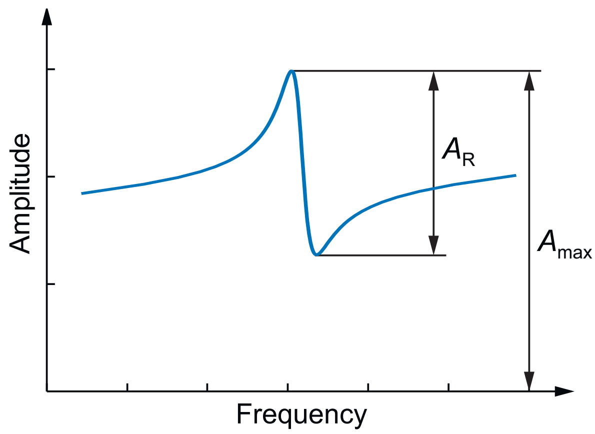

Figure 7: Resonance with parasitic signal component; the maximum amplitude of the resonance behavior is smaller than the maximum of the overall signal.

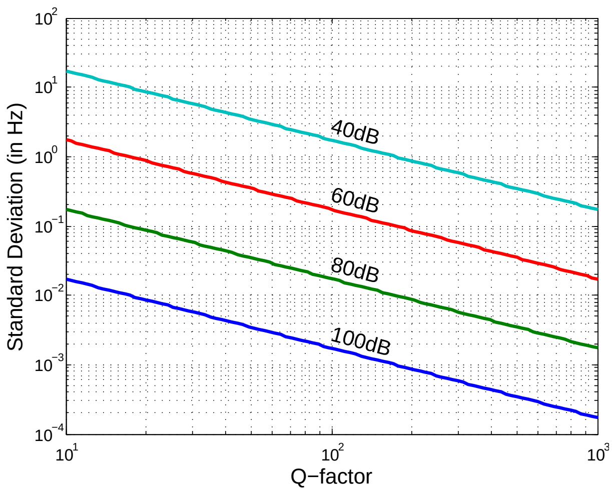

Figure 8: Typical standard deviation of measured resonance frequency for a resonator at 30 kHz as function of Q and $\mathrm{SNR_R}$.

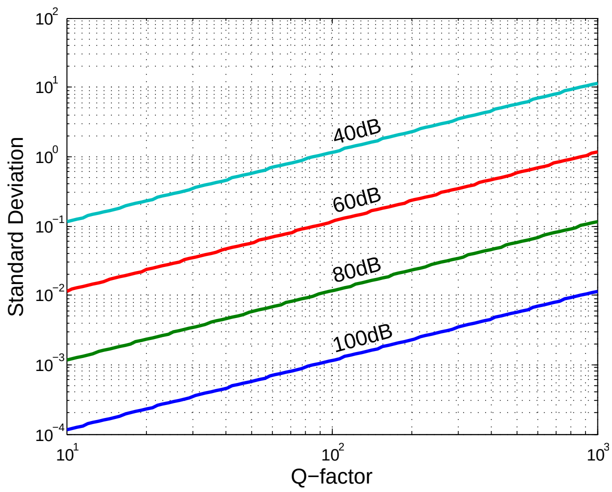

Figure 9: Typical standard deviation of measured quality factor for a resonator at 30 kHz as function of Q and $\mathrm{SNR_R}$.

Revision History

01/2018 Preliminary Revision

Specifications subject to change without notice.

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